The Chief of Naval Operations wrote to the Bureau of Ordnance September 15, 1955, noting that a laydown bomb family with the range of yields noted above might require two different nuclear designs. One would be the single-stage XW-34 and the other might be an adaptation of the Mk 28 thermonuclear bomb.[14]

The military characteristics for the XW-34/LULU depth bomb were approved by the Military Liaison Committee October 4, 1955.

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The length and weight of the weapon would be held to a minimum, and not exceed 26 inches and 300 pounds, respectively.

The power supply would be a thermal battery. Since incorporation of this type of cell in a sealed package was undesirable from the standpoints of safety and surveillance, the battery would be located outside the sealed package. The operational requirements dictated that the depth bomb be capable of remaining in a completely assembled and ready-for-use condition, without loss of reliability, for a period of at least 180 days or 1000 flight hours, whichever occurred first. The weapon would be able to withstand linear accelerations of -2000 g's and +100 g's along the longitudinal axis, an acceleration of 800 g's along any axis perpendicular to the longitudinal axis, and angular accelerations about the longitudinal axis of 300 radians per second per second.[15]

The Assistant Secretary of Defense wrote to the Atomic Energy Commission October 6 1955, requesting that LULU and HOTPOINT feasibility studies be combined.[16]

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The initial step in this project would be to develop a bomb with a weight not over 1500 pounds and having a time-delay feature to permit release from very low altitudes and allow safe escape of the delivery aircraft.[17]

The Special Weapons Development Board discussed the laydown program in a meeting October 26, 1955. The feasibility study would be completed by December 1956, and impacts with such targets as aircraft runways. A feasibility study was started on this design, which became the Mk 34 weapon.

The Step II weapon would be capable of being delivered at low altitudes by low-angle pitch-off or over-the-shoulder tactics. Fuzing would be air burst with a contact cleanup option. There would be preflight selectability between timer and radar, and inflight choice between radar and contact options. The air-burst height would be such as to eliminate severe residual contamination.

(b)(1), (b)(3)

Delivery would be by Navy AD4 aircraft. This Step II weapon became the Mk 28 Mod 2 Bomb.

The Step III weapon was a long-term development combining the characteristics of Steps I and II, and it would depend on future design progress. The device would be capable of delivery at both low and high altitudes, and at speeds over Mach 0.9.

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This design would provide the Services with a single weapon or weapon family having tactical fuzing capabilities of air burst, ground contact, and delayed laydown options. This design became the Mk 43 Bomb.[20]

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Sandia forwarded the product definition for the XW-34 to Santa Fe Operations Office February 13, 1956. It was anticipated that the design could be released in April 1957, with early production in the second quarter of calendar year 1958.

(b)(3)

(b)(3) The overall depth bomb would be 18 inches in maximum diameter and 96 inches long, and would weigh about 1200 pounds. The depth bomb would be capable of internal or external carriage and delivery from low altitudes. Both timer and hydrostatic pressure fuzes would be provided.

Sandia would be responsible for nonnuclear bomb components and any associated test and handling equipment. The Naval Ordnance Laboratory would be responsible for the LULU adaption kit, including pressure hull and fuzing and arming system. The high-explosive case would be an aluminum sphere consisting of two caps with a center seal, and would be enclosed by the pressure hull. The battery assembly would contain five permanently potted thermal cells connected in series with an output of 2500 volts. An arm/safe switch would incorporate a motor, low- and high-voltage switches, and requisite circuits and hardware, all enclosed in a metal container. This switch could be operated by the pilot of the carrying aircraft through application of aircraft power.[22]

By early 1956 work was in progress on several components to be used in the Xw-34 program. One was a low-voltage thermal battery, with the capability of firing a squib switch and matches in the high-voltage thermal batteries, and of pulsing the X-unit gap. A battery life of 100 seconds was desired, and it was believed that a 28-volt thermal cell being developed by the Naval Ordnance Laboratory would be suitable. Another component was a switch whose contacts were closed until a deceleration of at least 15 g's was experienced. Another set of contacts were closed until a deceleration over 20 g's was experienced.

A safe-separation timer with a fixed time of 17 seconds and a fuzing timer with a fixed time of 6.25 seconds were needed, and it was felt that pyrotechnic devices being developed by the Naval Ordnance Laboratory could be used. Since there was only limited space available for the fuzing system, each component would have to be as small as possible. The fuze would be potted to withstand the shock of water entry.[23]

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Revised military characteristics for the LULU depth bomb were released by the Military Liaison Committee March 27, 1956. These noted that the weapon was a small-diameter, lightweight atomic bomb to be used in attack of submarines by carrier-based aircraft. The immediate objective was a weapon with some delivery restrictions and available for operational deployment April 1, 1958. The ultimate objective was a weapon capable of unrestricted delivery, including an ability to be dropped into shallow bodies of water and operate satisfactorily.

The maximum speed for external carriage was 300 knots, and the maximum launch altitude was 600 feet.

(b)(1), (b)(3)

It was hoped that the weapon would maintain reliability for at least 1000 flight hours. This would include three patrols per day, each of 4-hour duration, for a period of 90 days. Each patrol would start with a catapulted takeoff and end with an arrested landing.[25]

Report SC3759(TR), Proposed Ordnance Characteristics of the XW-34 Warhead for the LULU Depth Bomb,[26] was discussed in the 100th meeting of the Special Weapons Development Board held April 25, 1956, and this report was subsequently forwarded to the Division of Military Application.

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If the weapon was dropped into shallow water, it would be detonated by timer.

The watertight pressure hull of the LULU could withstand 1000-pounds-per-square-inch water pressure. The hull was internally pressurized with a dry gas at 5 or 10 pounds per square inch, and any need for desiccant was thus eliminated. The afterbody was an aluminum sheet-metal cone perforated for rapid flooding. Two pieces of handling equipment were required, a storage/shipping container and a handling sling. Two test sets were designed, one to monitor the electrical circuits and the other to detect leakage of deuterium-tritium gas.

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The X-unit held four capacitors, dual-probe gap, and two gap trigger transformers. The high-voltage battery package contained five thermal batteries, two battery squib transformers, two thermal fuses, five silicon diode nets and two monitor switches.

A battery monitoring device indicated whether the thermal batteries had been fired. Thermal fuses were mounted near the outside edge of the potting and would melt in the event of aircraft fire before the battery heat-powder matches could ignite. Silicon diodes were installed in parallel with each battery to allow bypassing of defective units.

Special safety provisions were furnished. A safing plug grounded the boosting system, high-voltage battery initiation squibs, and all low-voltage pins. The high-voltage battery pack was not installed until preflight operations were in progress. The inflight safing switch opened the high-voltage circuit and grounded the capacitor bank, and the switch remained in this position until just before bomb release. A hydrostat switch in the adaption kit blocked arming and firing signals until it closed at the proper water depth.

The Navy desired that the weapon be compatible with all carrier-based aircraft planned through 1960. Requirements were for launches from altitudes of 0 to 600 feet and at release speeds of 0 to 300 knots; and it was hoped that launches could be made at altitudes as high as 2000 feet and speeds up to 600 knots. In water of less than 20-foot depth, a launch altitude of 150 feet and speed of 150 knots were specified.

(b)(1), (b)(3)

It was felt that the best way in which to provide this weapon, which could be delivered from low altitudes and high speeds with good accuracy, was through modification of the LULU design.

Subsequently, the Assistant Secretary of Defense wrote to the Atomic Energy Commission, September 19, 1956, noting that the feasibility study of a tactical/lay-down weapon family had been completed.

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Thus, in order to satisfy urgent requirements, it was requested that the Atomic Energy Commission cooperate with the Navy in the development through production of the XW-34/HOTPOINT. This weapon would utilize LULU depth-bomb components, modified to increase shock resistance, and the Navy was assigned cognizance of the Department of Defense portion of the work.[28] Albuquerque Operations Office subsequently established a tentative operational availability date of October 1958.[29]

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The LULU Coordinating Committee replied that there appeared to be two methods for accomplishing this result.

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A meeting was held December 4 1956 with personnel of the Applied Physics Laboratory of the University of Washington, to discuss possible atomic devices for an antisubmarine torpedo, the ASTOR. This torpedo was 19 inches in diameter and 20 feet long.

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Atomic devices that could be applied to the ASTOR included the XW-34, XW-40 and possibly XW-25.[33]

Sandia wrote to Albuquerque Operations Office April 8, 1957, noting that there might be some logistical advantage to be gained by applying XW-34 to ASTOR.[34] Subsequently, the Assistant Secretary of Defense, May 14, 1957, requested the Atomic Energy Commission to proceed with development engineering adaption of the XW-34 to ASTOR.[35] Since the ASTOR would only have to withstand 60-g shock, 3-g vibrational environment, and a temperature range from -65°F to +130°F, the XW-34 could be used without modification.[36]

Identification of Mk 101 Mod 0 Depth Bomb had meanwhile been assigned to LULU, and production nomenclature of Mk 34 Mod 0 to the warhead.[37,38] The Mk 34 design was released in May 1957, with the exception of external initiators and final-assembly tester.[39] These items were released by October 1957.

The HOTPOINT weapon was discussed in the June 20, 1957 meeting of the Special Weapons Development Board. Target approach could be made at minimum altitude, which made detection of carrying aircraft difficult. Since delivery and escape maneuvers placed minimum burden on the pilot, special flight skill and training were not needed, and aircraft safety was enhanced. Attacks could be made from any direction, since an identification point was not necessary, and target identification became more positive. There were, of course, some disadvantages. The surface burst of the weapon produced ground contamination, and the combination of low-altitude and high-speed flight consumed aircraft fuel at a high rate. However, the advantages far outweighed the disadvantages.

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The weapon would be 19 inches in diameter, 162 inches long, and weigh about 1400 pounds. The tail cone would be explosively jettisoned 1/4 second after release of the bomb from the carrying aircraft, and an extraction parachute deployed. Another 1/4 second later, the afterbody would be detached by detonation of explosive bolts and pulled away from the weapon by the extraction parachute, thus releasing the main parachute.

Since LULU had been designed to withstand axial deceleration of 2000 g's combined with lateral shocks of 800 g's, it was felt that a suitable laydown weapon could be

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It was felt that the HOTPOINT was a good interim weapon. There were practically no limitations on the low-altitude delivery capability of the system, and the weapon was demonstrably rugged. In one test, the main parachute failed when the bomb was dropped from an altitude of 67 feet and a speed of 510 knots. A bomb containing live high explosive struck the ground with an impact velocity of 650 feet per second and slammed 3500 feet down a concrete runway before stopping. The drop was a severe overtest of the entire system but only minimal damage resulted, and the unit would have fired successfully.[42]

Meanwhile, LULU testing had been proceeding. Drop tests were made to determine that the weapon would enter the water at low angles without ricocheting. In 25 drops, angles from 6 to 30 degrees were tested at weapon impact speeds of 300 to 550 feet per second. Satisfactory results were obtained, as well as those from several hundred air-gun tests on components and assemblies.[43]

A cookoff test was conducted, in which the weapon was subjected to a gasoline fire for a period of about 30 minutes. During this test, temperatures as high as 1650°F were recorded, and there was a low-order explosion of the weapon after more than 13 minutes of fire. Test results indicated that there would be ample time to take necessary action in the event of fire following an airplane crash.[44]

Water drops of inert LULU weapons were conducted with extremely satisfactory results.[45]

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The shock resistance of the weapon exceeded all expectations and no damage to fuzing or firing systems was recorded. Additional water drops were made, with the weapons being subjected to temperature and humidity preconditioning. In these tests, which used weapons progressively closer to full production status, equally satisfactory results were obtained.

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It was the opinion of the Committee that the LULU met or exceeded the military characteristics.

The capability for bomb release at altitudes of less than 50 feet had not been conclusively proven, as the tail of one test aircraft had been hit by the water splash of the bomb when released from this altitude, and testing at this height had been subsequently discontinued.

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These drops were highly successful.[49]

The Mk 34 Mod 0 Warhead was design-released for use in LULU July 28, 1958.[50] Report SC4155(TR), Final Evaluation of the Mk 34 Mod 0 Warhead (LULU Application),[51] was presented to the August 20, 1958 meeting of the Special Weapons Development Board. The device was designed primarily for application in the LULU depth bomb, but could also be used with the ASTOR and HOTPOINT weapons.[52]

Meanwhile HOTPOINT testing had been proceeding. Air-gun firings were made, using live high-explosive spheres and simulated nuclear assemblies in some cases, and simulated spheres and live nuclear assemblies in others. The target was a concrete slab, and impact velocities ranged from 180 to 250 feet per second and impact angles from 8 to 60 degrees. One aluminum battery housing was ruptured during tumbling of the bomb after impact, and this material was changed to steel. An external initiator was included in the most severe test in the series and resulted in a cracked electronic tube and a slow leak, but the weapon probably would have functioned at the time of impact.[53]

Production authorization for the Mk 34/ASTOR was issued in March 1959, and an operational date of October 1960 was established. Since the ASTOR environment was much less severe than that of LULU and HOTPOINT, only a few tests were required to prove compatibility.[60] These included environmental tests of the torpedo compartment containing the Mk 34 and electrical tests of the system. A series of four fuzing and firing runs of the complete torpedo and Mk 34 were successfully conducted in mid-1959.

Report SC4750(WD), Final Evaluation of the Mk 34 (Mods 2, 3 and 4) Warhead to the Mk 45 (Mods 0 and 1) Torpedo (ASTOR), was published in June 1963. This report noted that at the time of development authorization, the torpedo was scheduled to be operational in the spring of 1960. Due to budget restrictions, the operational date was delayed until late 1962. The first release of the warhead for use in the ASTOR was October 10, 1960, with the Mk 34 Mod 1 (see later paragraphs for Mod 1 description) Warhead. Later, the Mods 2, 3 and 4 were also released for ASTOR use, and eventually a decision was made to use only the Mods 3 and 4.[61]

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The bleeder resistors were placed in the neutron generators.

It was later decided to install a shielded pullout cable and a filter pack in the electrical circuit to attenuate any induced currents. The bleeder resistor was changed to 15 ohms, and this change constituted the Mk 34 Mod 3. A still further change, this time back to the 30-ohm bleeder resistors, resulted in the Mk 34 Mod 4 Weapon.[65]

Depth Bomb -- An explosive charge that detonates after sinking to a prescribed depth in water.

Detonators -- Explosive devices which, when initiated by the X-unit, ignite the lens charges of the high-explosive sphere.

Deuterium -- The hydrogen isotope of mass number 2.

Division of Military Application -- An AEC office that functions as liaison between the Military and weapons designers and producers.

Drogue Parachute -- A parachute that slows the rate of fall of a bomb.

Explosive Bolt -- A bolt containing a small charge of explosive. When detonated, the bolt fractures.

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Firing System -- The electrical system of the weapon that produces and applies a high-voltage current to the detonators.

Fuzing System -- The system that arms the weapon at the appropriate time and provides a firing signal to the firing system at the selected burst height.

g -- Force equal to one unit gravity.

Gap Switching -- An air gap normally prevents passage of electrical current. When this gap is ionized, it will act as a conductor.

Gas Boosting -- The technique of increasing the yield of a nuclear device by introducing deuterium-tritium gas into the implosion process to increase fission activity.

Gun-Type Design -- An atomic weapon based on the principle that a supercritical mass of nuclear material can be created by bringing together two subcritical masses of such material.

High-Explosive Sphere -- The ball of high explosive that surrounds the nuclear ~~primary~~ pit and capsule and is designed to produce the implosion effect when detonated.

Hydrostat -- A pressure switch which closes at a prescribed water depth.

Implosion -- The effect created when a sphere of high explosive is detonated on it exterior surface. If suitable lens charges are provided to invert the explosion, the force of the shock wave is directed largely toward the center of the sphere.

Initiator -- A source of neutrons.

Joint Chiefs of Staff -- A group composed of the Chiefs of Staff of the Army, Navy and Air Force to determine policy and develop joint strategic objectives of the Armed Forces.

Joint Task Force -- A military group established to test the stockpile-to-target sequence of a weapon.

Kiloton -- A means of measuring the yield of an atomic device by comparing its output with the effect of an explosion of TNT. A 1-kiloton yield is equivalent to the detonation effect of 1000 tons of high explosive.

Knot -- A naval unit of speed, equivalent to 1 nautical mile or 6076 feet per hour.

Laydown Device -- A bomb capable of being dropped on a relatively hard target or surface and surviving in a condition to later detonate.

Lenses -- As applied to nuclear weapons, lenses are elements of the high-explosive sphere, which are designed to produce an implosion. The lens charge is composed of high explosives of different burning rates and is so constructed and shaped as to change the explosion initiated by the detonators into an implosive force which converges smoothly on the nuclear materials.

Los Alamos Scientific Laboratory -- A nuclear design organization located at Los Alamos, New Mexico.

Mach -- A measure of speed. Mach 1.0 is the speed of sound, or 738 miles per hour at sea level.

Matches -- As used in this history, matches are small charges of flammable material that are ignited by an electric spark. The flammable material heats up the solid electrolyte in the thermal battery, and places the battery in operating condition.

Megaton -- A measure of yield of a large weapon. One megaton is the equivalent of 1,000,000 tons of high explosive.

Microsecond -- One millionth of a second.

Military Characteristics -- The attributes of a weapon that are desired by the Military.

Military Liaison Committee -- A Department of Defense Committee established by the Atomic Energy Act to advise and consult with the AEC on all matters relating to military applications of atomic energy.

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One-Point Safety Test -- A test in which the high-explosive sphere is detonated at one detonator or point. If the device is one-point safe, no nuclear yield is produced.

Operation Plumbbob -- See Plumbbob.

Operation Redwing -- See Redwing.

Operation Teapot -- See Teapot.

Operation Wigwam -- See Wigwam.

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Radar -- Named for Radio Detecting and Ranging. Radars emit a pulse of high-frequency energy and measure the time lapse from that transmission to receipt of a reflected electrical "echo" from an object. This time measurement determines the distance of the object from the transmitting antenna of the radar.

Radar Option -- The option of detonating the weapon by radar, which can be set to trigger the weapon at a given height above the terrain.

Redwing -- A full-scale nuclear series of 17 tests held at the Pacific Proving Grounds from May 4 to July 21, 1956.

Reservoir -- As used in this history, a container for deuterium-tritium boosting gas.

Ring Lenses -- High explosive lenses formed in the shape of a ring to occupy less radial space.

Rotochute -- A device to slow down the rate of descent of a free-fall weapon. Consists of counterrotating propeller blades which absorb energy.

Santa Fe Operations Office -- The local office of the Atomic Energy Commission (AEC) concerned with Sandia operations.

Sealed Pit -- A weapon in which all the nuclear components (except the boosting gas, when used) are permanently installed in place. Designed to eliminate the need for inflight nuclear insertion mechanisms.

Services -- The Department of Defense.

Sonar -- A system for locating objects by echo reflection of sound waves from an object.

Special Weapons Development Board -- A joint Sandia-Military board at Sandia Base to provide local guidance on weapons design.

Squib -- A device containing a small powder charge. When detonated, the resulting gas pressure closes a switch or performs a similar action. A light, quick-acting, one-shot device.

Tactical -- Use of a weapon against troops or concentrations of war materiel.

Teapot -- A less-than-full-scale test series held at the Nevada Test Site. Series of 14 tests, starting February 18 and ending May 15, 1955.

Thermal Battery -- A battery whose electrolyte is in a solid state while inactive. To activate, heat is applied to this electrolyte, melting it and putting the battery into active output condition.

Tritium -- The hydrogen isotope of mass number 3.

Uranium-235 -- A radioactive element, an isotope of uranium-238.

Uranium-238 -- A radioactive element, atomic number 92. Natural uranium contains about 99.3-percent uranium-238; the rest is uranium-235.

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<u>X-Unit</u> -- A device used to provide high voltage to the weapon detonators.

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